PATENT

OIPE JC139 FEB 0 5 2002 PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE 2856

#5 Priority Paper 5-16-02 RAtoles

In re Application of	BATEMAN ET AL.	)	
		)	**Art Unit:** 2856
		)	
Serial Number:	**09/995,662**	)	**Examiner:** N/A
		)	
Filed:	**November 29, 2001**	)	**Atty Docket:** DEH009

For: MASS SPECTROMETERS AND METHODS OF MASS SPECTROMETRY

THE COMMISSIONER OF PATENTS AND TRADEMARKS
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Respectfully submitted,

Everett G. Diederiks, Jr.
Attorney for Applicant
Registration Number: 33,323

Date: February 5, 2002

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Patents Form 1/77

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1/77

29NOV00 E587606-1 D00027
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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

1.	Your reference	85.74444
2.	Patent application number *(The Patent Office will fill in this part)*	0029088.2 — 29 NOV 2000
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Micromass Limited Floats Road, Wythenshawe Manchester, M23 9LZ United Kingdom
	Patents ADP number *(if you know it)*	6996102001
	If the applicant is a corporate body, give country/state of incorporation	United Kingdom
4.	Title of the invention	Ion tunnel
5.	Name of your agent *(if you have one)*	Frank B. Dehn & Co.
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	179 Queen Victoria Street London EC4V 4EL
	Patents ADP number *(if you know it)*	166001
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country / Priority application number *(if you know it)* / Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application / Date of filing *(day / month / year)*
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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Claim(s)	-
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Priority documents	-
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Request for preliminary examination and search *(Patents Form 9/77)*	-
Request for substantive examination *(Patents Form 10/77)*	-
Any other documents *(please specify)*	-

11. I/We request the grant of a patent on the basis of this application.

Signature Date 29 November 2000

12. Name and daytime telephone number of person to contact in the United Kingdom

P.M. Jeffrey
01273 244200

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Ion Tunnel

Background and Prior Art

The use of rf only multipoles for transport, focussing and trapping of ions as well as conversion of discontinuous ion beams to continuous ones when used in higher pressure vacuum stages is well established and subject of several patents. A less well known rf device for collimating or trapping ions uses a stack of ring electrodes and was first developed to trap ions for the study of ion-molecule reactions or laser interactions with ions. A later development of the ring electrodes employs a stack with decreasing internal diameter to collimate, concentrate and transport ions through a high-pressure vacuum stage.

The first ring electrode device was developed in 1969 by Teloy and Bahr[1] to study thermal rate coefficients of ion-molecule interactions. Further enhancements to the approach are summarised in the review paper by Gerlich[2]. The ring electrode device is made from a stack of metal plates or rings along an axis perpendicular to the central apertures and with fixed spacing. An rf voltage is then applied with 180° phase shift on adjacent plates which generates a effective potential along the axis which has a broad minimum in the radial direction but increases rapidly (exponentially) in the proximity of the electrodes. The field acts to contain ions to the central, low potential, region of the device. In the presence of a sufficient buffer gas in the assembly, ion kinetic and internal energy can be quenched essentially to that of the buffer gas. Consequently, in a typical experiment ions are injected and trapped in the ring electrodes where they undergo collisions with the buffer gas and/or a reagent gas. After a certain reaction time an extraction field is applied and the ions mass analysed and detected. This process is repeated for various trapping times to obtain a reaction rate coefficient.

A more recent manifestation of the ring electrode device has been pioneered by Smith and co-workers at Battelle[3-7] to efficiently transport and focus ions in the relatively high pressure (1-10 Torr) vacuum stages of mass spectrometers operating with API sources. This device uses a stack of ring electrodes with continually decreasing aperture size to provide a large acceptance angle followed by focussing/collimation of the ion beam to a small diameter suitable for passage through a differential aperture into the next vacuum stage of the instrument. In this design, the rf is applied in the same manner as above to adjacent plates, but additionally a dc voltage gradient is provided along the axis of the 'tunnel' to force the ions in the direction of the smaller apertures.

In the Smith group's latest design of ion funnel[7] a region of plates with constant aperture diameter has been added to the entrance of the ion funnel to reduce the gas dynamic effects upon ion confinement, to improve conductance for pumping, reduces gas load downstream and provides an extended ion residence time for enhanced desolvation.

In a recent publication by Smith and co-workers[8] the ring electrode device is considered with constant internal diameter apertures with regard to trapping properties

compared to standard multipole assemblies. This paper deals only theoretically with the trapping properties of these devices.

A recent patent application[9] deals with the use of a tapered ring electrode device with changing aperture shape to modify an ion beam shape prior to entry into an oa-ToF mass analyser. This device is reported to improve resolution in the analyser through reduction of the beam dimension in the time-of-flight direction. In addition, use of the device for ion fragmentation is also reported.

Present Design and Application

We have built a ring stack device with constant diameter apertures for use in the millibar vacuum region of the Quattro Ultima currently occupied by hexapole 1. This 'ion tunnel' directly replaces hexapole 1 and is used to guide/collimate/focus ions from the source block to the vacuum stage containing the second hexapole.

At present the tunnel uses plates of 5mm internal diameter spaced by 1mm and overall is around 125mm in length. The rf is supplied by a standard generator operating at 750 kHz with peak-to-peak voltages in the range of 0 to 350V. No dc voltage gradient is currently applied along the axis of the device however the facility to float assembly to a fixed voltage is available.

This ion tunnel appears to be at least as efficient as the standard hexapole for transmission of ions. Improvements in transmission, particularly at low mass have been realised through use of a source block with the extraction 'cone' replaced by a tunnel, possibly as a result of collimation of the gas/ion stream closer to the axis of the ion tunnel.

Further embodiment:

Continuous ion tunnel between different pressure regions with one or more lens plates forming a differential pumping aperture to improve ion transmission.

References

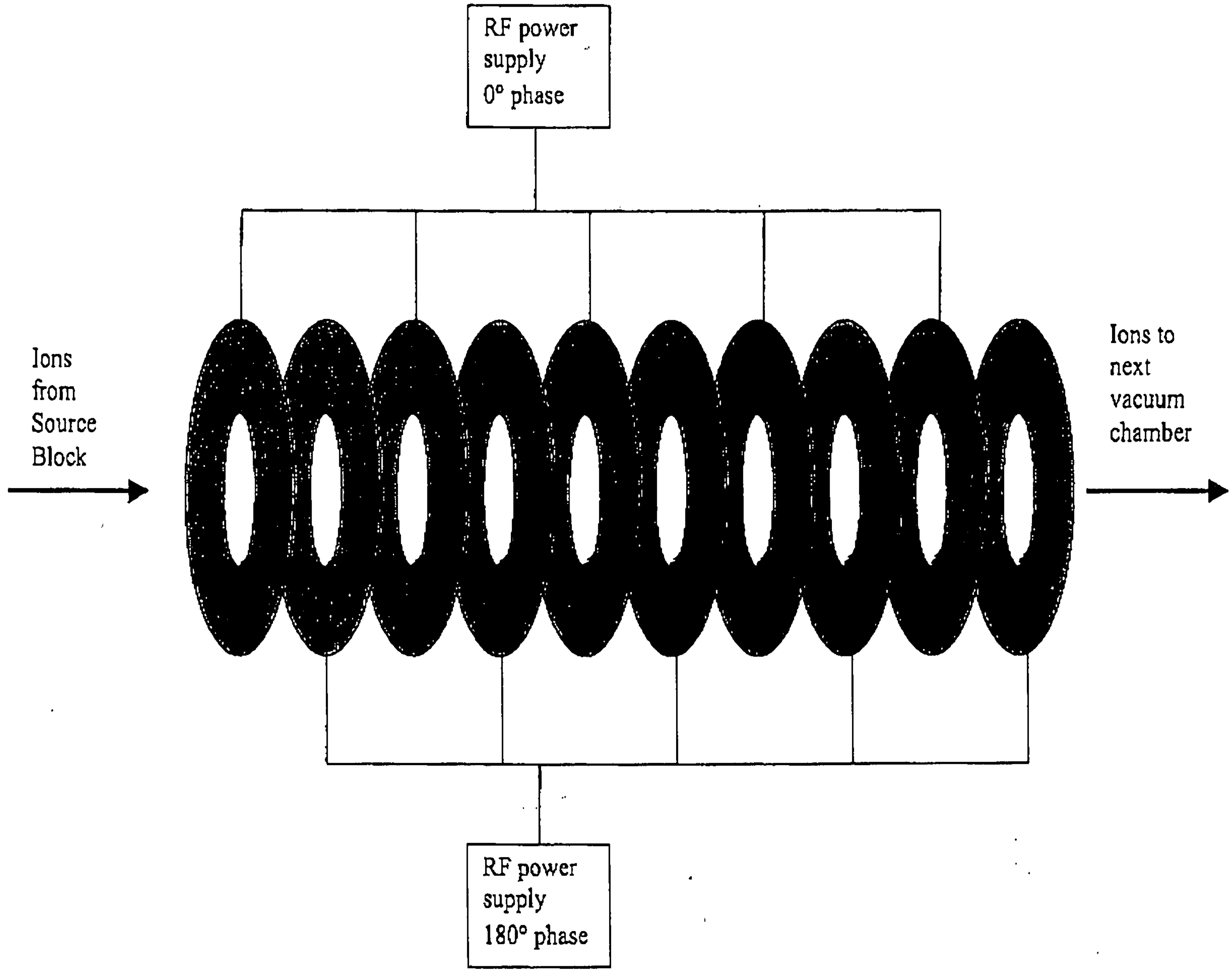
1) Bahr R, Gerlich D and Teloy E, (1969) Verhandl. DPG (VI) 5, 131
2) Gerlich D, in State Selected and State to State Ion Molecule Reaction Dynamics, Part 1: Experiment. Eds CY Ng and M Baer, Advances in Chemical Physics Series, Vol. LXXXII, 1992. Wiley. Pages 93-99.
3) Patent US6107628, 'Method and Apparatus for Ion and Charged Particle Focusing', Smith RD, Tang K and Anderson GA. 1997.
4) Shaffer SA, Teng K, Anderson GA, Prior DC, Udseth HR and Smith RD, Rapid Commun. Mass Spectrom, 11 (1997) 1813-1817
5) Shaffer SA, Prior DC, Anderson GA, Udseth HR and Smith RD, Anal. Chem., 70 (1998) 4111-4119
6) Shaffer, SA, Tolmachev A, Prior DC, Anderson GA, Udseth HR and Smith RD, Anal. Chem., 71 (1999) 2957-2964
7) Kim T, Tolmachev AV, Harkewicz R, Prior DC, Anderson GA, Udseth HR, Smith RD, Bailey TH, Rakov S and Futrell JH, Anal. Chem., 72 (2000) 2247-2255
8) Tolmachev AV, Udseth HR and Smith RD, Anal. Chem., 72 (2000) 970-978
9) Jolliffe C and Thomson B, Patent application 'Mass Spectrometer with Tapered Ion Guide' 1998 (internal ref. No. 12804)

(G) An illustrative schematic of the electrodes and supplies for the RF-only ion tunnel
(H) An illustrative schematic of one of our existing arrangements with an atmospheric pressure ion source, where we use two RF-only hexapoles to transport ions through regions of relatively high pressure – where (pressure x path length) > 0.01 mbar-cm.
(I) An illustrative schematic of a similar arrangement where the first of the two RF-only hexapole lenses is replaced by an RF-only ion tunnel to transport ions through a region of relatively high pressure – where (pressure x path length) > 0.01 mbar-cm.
(J) An illustrative schematic of a similar arrangement where both the RF-only hexapole lenses are replaced by two RF-only ion tunnels to transport ions through regions of relatively high pressure – where (pressure x path length) > 0.01 mbar-cm.
(K) Manufacturing drawing of the Ion Stack Assembly actually used in our prototype ion tunnel design.

Please note that these sketches illustrate schemes for transporting ions from an atmospheric pressure ion source through to a quadrupole mass filter. The device could be used to transport ions from a variety of different ion sources, including pulsed ion sources such as matrix assisted laser desorption ionisation (MALDI), and into a variety of different mass analysers, including time-of-flight mass spectrometers.

(G)

Ion Tunnel Schematic



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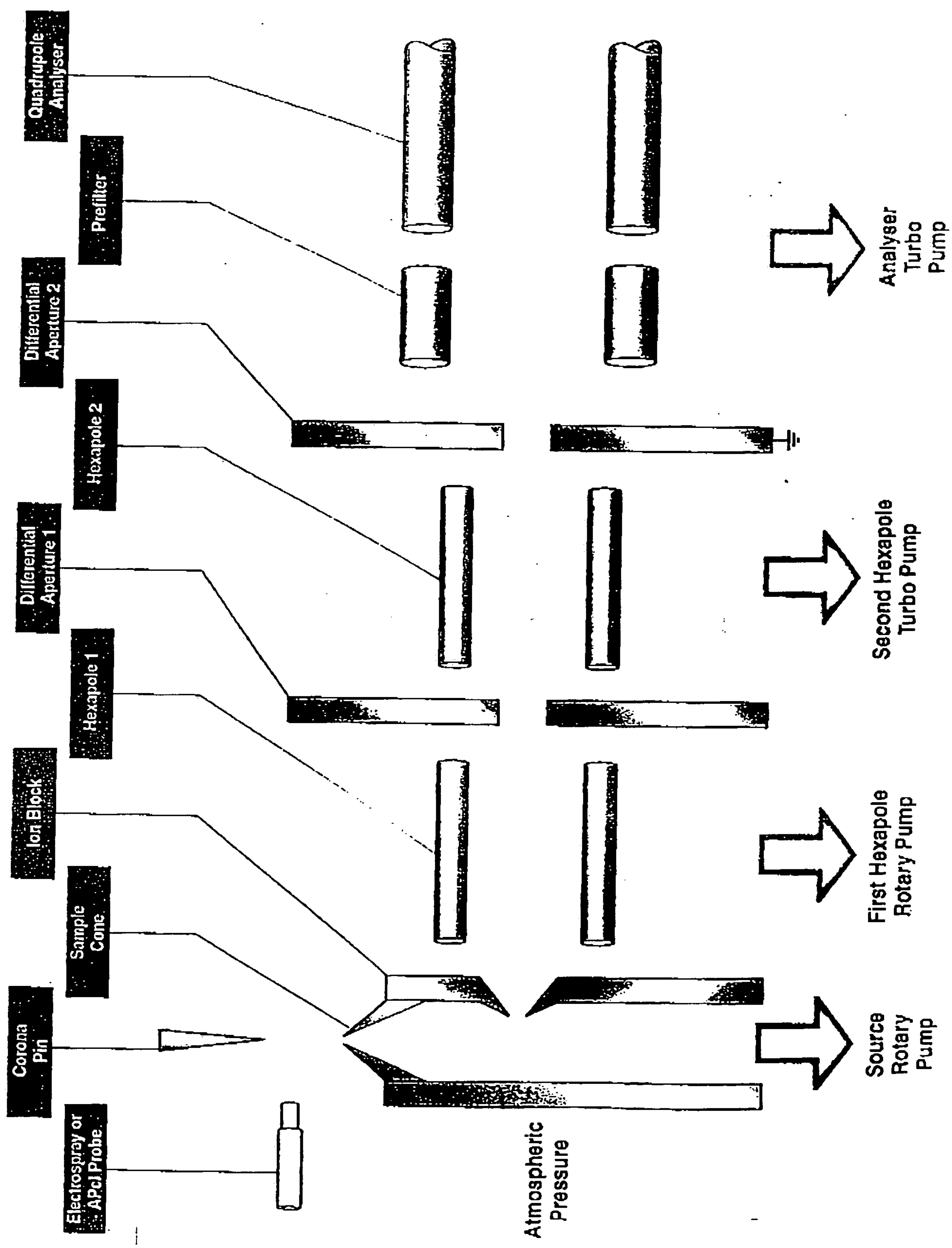
Quadrupole Analyser
Prefilter
Differential Aperture 2
Hexapole 2
Differential Aperture 1
Hexapole 1
Ion Block
Sample Cone
Corona Pin
Electrospray or APcI Probe
Atmospheric Pressure
Source Rotary Pump
First Hexapole Rotary Pump
Second Hexapole Turbo Pump
Analyser Turbo Pump

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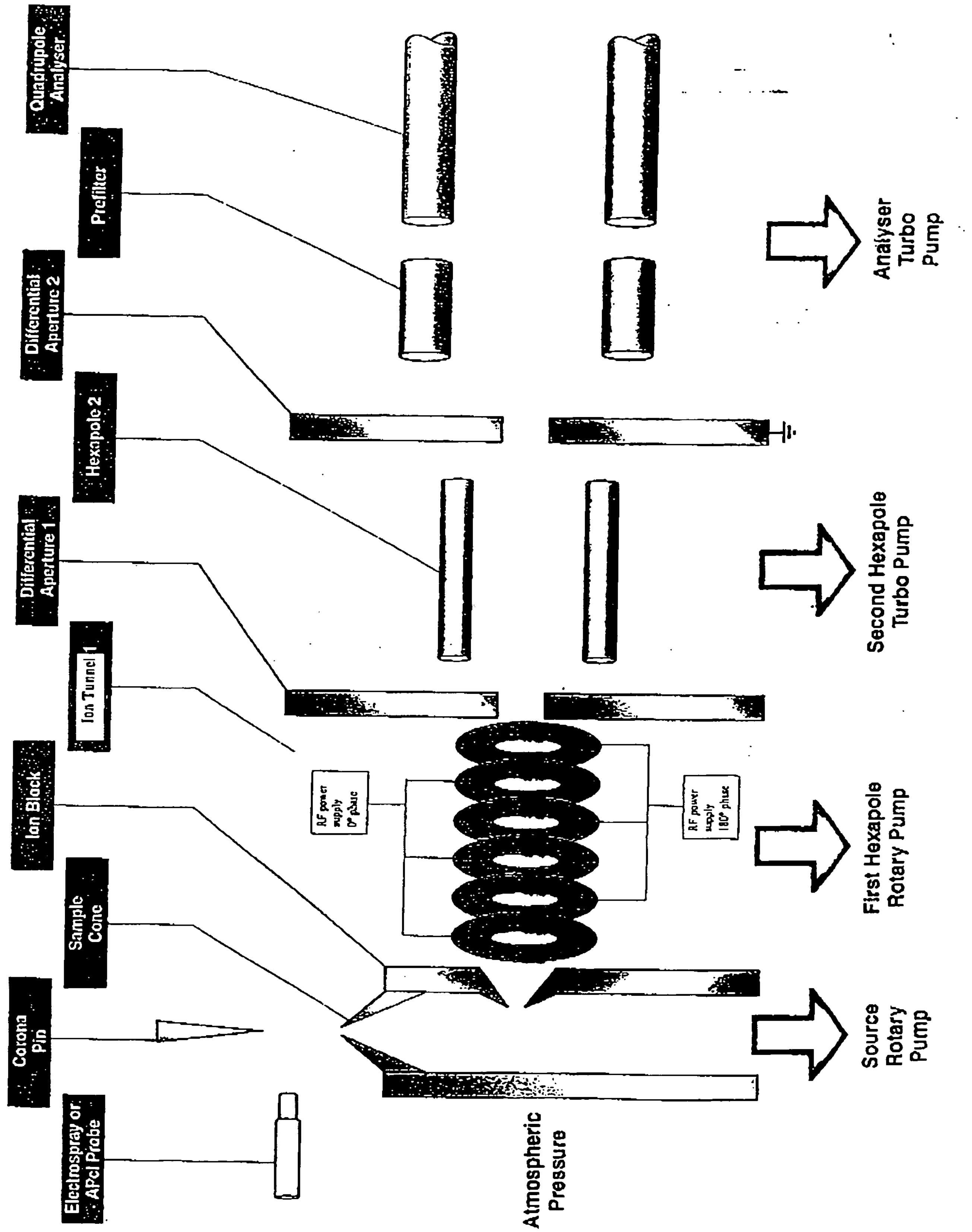
Quadrupole Analyser
Prefilter
Differential Aperture 2
Hexapole 2
Differential Aperture 1
Ion Tunnel 1
Ion Block
Sample Cone
Corona Pin
Electrospray or APcI Probe
RF power supply 0° phase
RF power supply 180° phase
Atmospheric Pressure
Source Rotary Pump
First Hexapole Rotary Pump
Second Hexapole Turbo Pump
Analyser Turbo Pump

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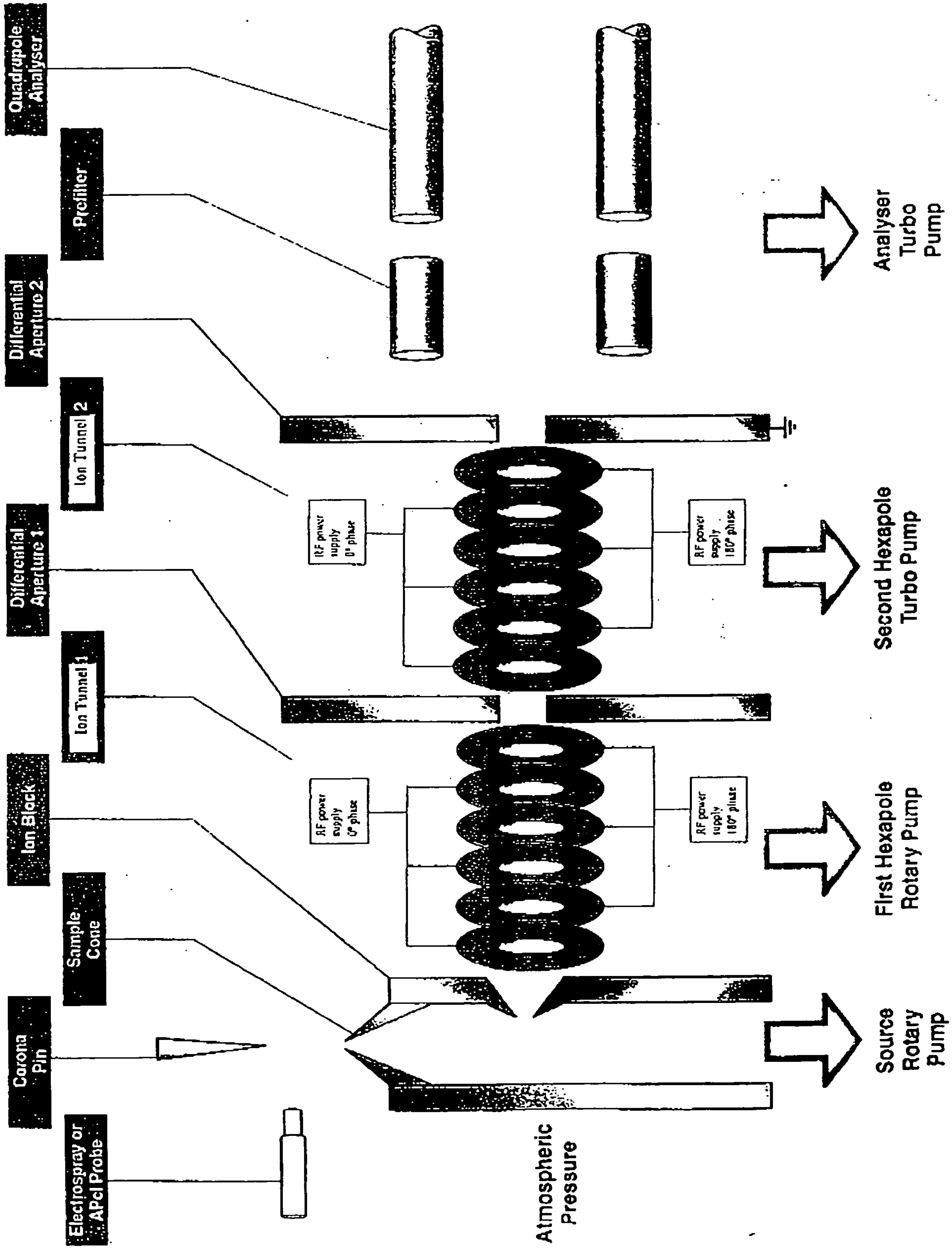
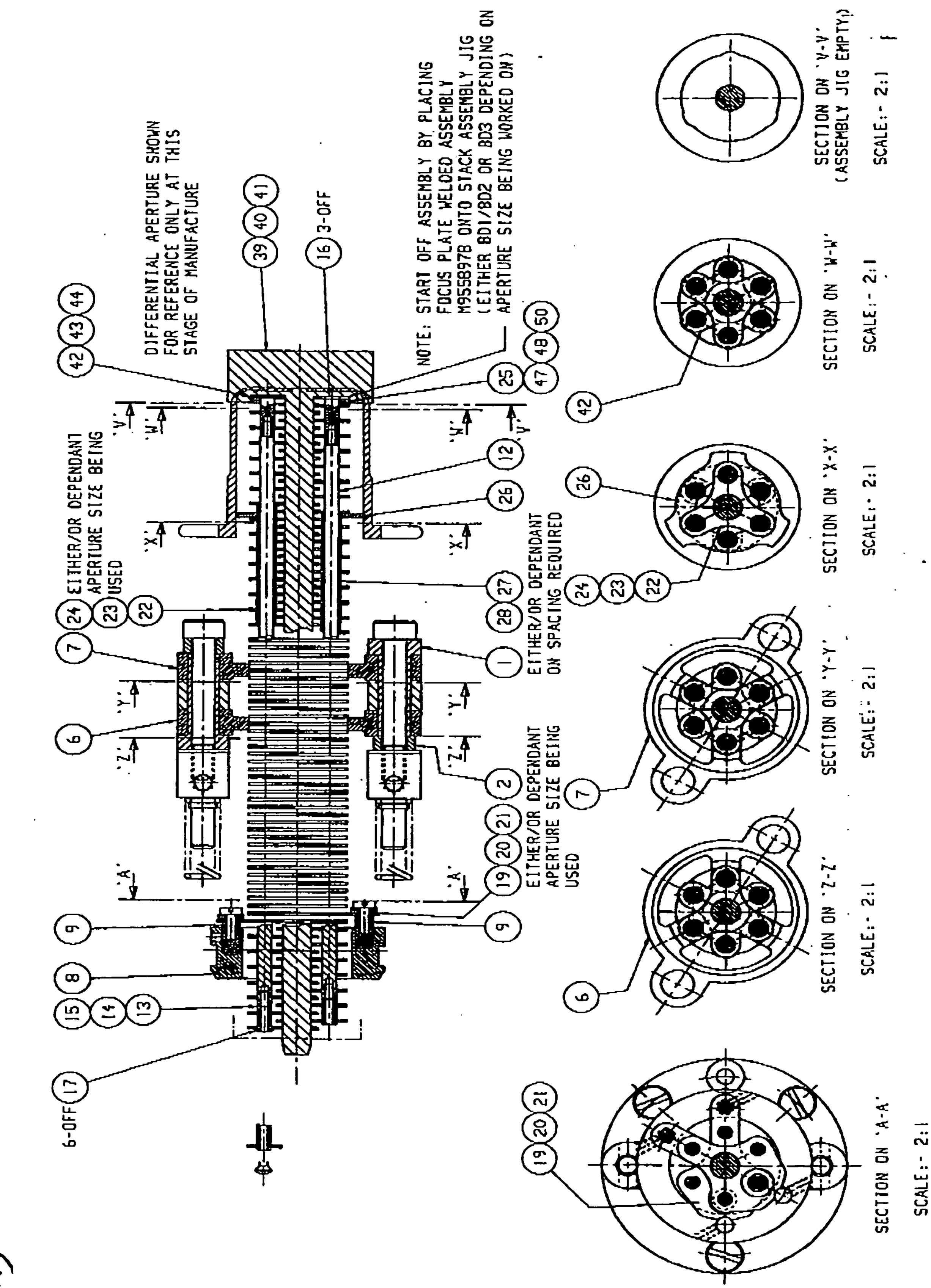

Electrospray or APcI Probe
Corona Pin
Sample Cone
Ion Block
Ion Tunnel 1
Differential Aperture 1
Ion Tunnel 2
Differential Aperture 2
Prefilter
Quadrupole Analyser
RF power supply 0° phase
RF power supply 180° phase
RF power supply 0° phase
RF power supply 180° phase
Atmospheric Pressure
Source Rotary Pump
First Hexapole Rotary Pump
Second Hexapole Turbo Pump
Analyser Turbo Pump


DIFFERENTIAL APERTURE SHOWN FOR REFERENCE ONLY AT THIS STAGE OF MANUFACTURE
NOTE: START OFF ASSEMBLY BY PLACING FOCUS PLATE WELDED ASSEMBLY M955897B ONTO STACK ASSEMBLY JIG (EITHER BD1/BD2 OR BD3 DEPENDING ON APERTURE SIZE BEING WORKED ON)
3-OFF
EITHER/OR DEPENDANT APERTURE SIZE BEING USED
EITHER/OR DEPENDANT ON SPACING REQUIRED
EITHER/OR DEPENDANT APERTURE SIZE BEING USED
6-OFF
SECTION ON 'V-V' (ASSEMBLY JIG EMPTY)
SCALE:- 2:1
SECTION ON 'W-W'
SCALE:- 2:1
SECTION ON 'X-X'
SCALE:- 2:1
SECTION ON 'Y-Y'
SCALE:- 2:1
SECTION ON 'Z-Z'
SCALE:- 2:1
SECTION ON 'A-A'
SCALE:- 2:1